RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #15

Proposed DO-260A, Appendix A, additional Notes in regards to longitudinal CPR Accuracy

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SUMMARY
Appendix A currently infers an approximate end –to- end CPR accuracy of 5.1 meters in the Airborne state and 1.25 meters in the Surface state. Analysis has demonstrated that such is not the case near latitudes of either 87 degrees North or South. This Working Paper proposes the addition of appropriate notes to Appendix A that address the established situation.

1.0. Airborne CPR Encode/Decode

1.1. Airborne CPR Encode/Decode Concern

Appendix A provides the following in regards to Latitude and Longitude encoding in regards to the Airborne Position message:

> **A.1.4.2.3 Latitude/Longitude**
>
> The latitude/longitude field in the airborne position message will be a 34-bit field containing the latitude and longitude of the aircraft airborne position. The latitude and longitude will each occupy 17 bits. The airborne latitude and longitude encoding will contain airborne CPR-encoded values in accordance with §A.1.7. The unambiguous range for the local decoding of airborne messages will be 666 km (360 NM). The positional accuracy maintained by the airborne CPR encoding will be approximately 5.1 meters.
>
> ***Note:*** *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit) described above.*

Detailed analysis of the CPR Airborne Encoding and Decoding functions were performed several times using MATHCAD. These analysis have consistently indicated that the CPR encoding approximate accuracy of **5.1** meters does apply to virtually the entire possible encoding set with the exception that longitude accuracy will be partially compromised when the latitude is near **87** degrees North or **87** degrees South. This anomaly is probably attributed to the fact that the CPR algorithm must make a compromise in the selection of the NL zone at the **87** degree point.

The detailed analysis was conducted while keeping the receiving station (i.e., the decoder) separated from the transmitting station (i.e., the encoder) by **0.5** degrees in latitude and **0.5** degrees in longitude. After validation of the encoding for a given latitude and longitude position, the decoded position indicated the following longitudinal errors as the **-87** or **+87** degree latitude points were approached:

Observed Longitude Decoding Error				
Item #	**Input Latitude (degrees)**	**Input Longitude (degrees)**	**Odd Decoding Longitude Error (feet)**	**Even Decoding Longitude Error (feet)**
1	-88.0000	-175.5000	-14.00358562016069	-14.00358562016069
2	-87.5000	-174.5000	-21.39236854919383	-21.39236854919383
3	-87.0000	-173.5000	**-30.33446867187443**	**-30.33446867187443**
4	-86.5000	-172.5000	0.000622975280653	-10.20620402293134
5	-86.0000	-171.5000	-6.22002458100151	-17.88274862942549
6	-85.5000	-170.5000	-7.433968997478382	-13.99283534398812
7	+85.0000	+170.5000	-13.59964088927819	-13.59964088927819
8	+85.5000	+171.5000	0.437151004052041	-19.23944803547717
9	+86.0000	+172.5000	-0.000711836184596	-23.32615993303255
10	+86.5000	+173.5000	-5.442935027061655	-25.85658902348564
11	+87.0000	+174.5000	-26.83365981706823	-26.83365981706823
12	+87.5000	+175.5000	-26.25439188799625	-26.25439188799625
13	+88.0000	+176.5000	-24.11817668341401	-24.11817668341401
14	+88.5000	+177.5000	-20.42384415854166	-20.42384415854166
15	+89.0000	+178.5000	-15.17312976659349	-15.17312976659349

1.2. Airborne CPR Encode/Decode Recommendation

Review of the table above indicates a worse case error of **-30.33447** feet (**-9.24595** meters) at latitude **-87.00** degrees and longitude **-173.500** degrees. Also, at one degree away from **-87.00** degrees latitude, the error is **-17.88275** feet (**-5.45066** meters). Knowing that these minor excursions from the norm occur near the 87 degree latitude points, we must be careful in the specifications such that various verification, validation, certification echelons do not hold implementers of ADS-B to the **5.1** meter approximate limits currently called out in Appendix A. Therefore, it is herein recommended that the following restructure and note replace the existing note provided in section A.1.4.2.3.

> ***Note 1:*** *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit) described above.*
>
> ***Note 2:*** *Although the positional accuracy of the airborne CPR encoding is approximately 5.1 meters in most cases, implementers should be aware that the longitude position accuracy may only be approximately 10.0 meters when the latitude is either -87.0 +/-1.0 degrees or +87.0 +/- 1.0 degrees.*

2.0. Surface CPR Encode/Decode

2.1. Surface CPR Encode/Decode Concern

Appendix A provides the following in regards to Latitude and Longitude encoding in regards to the Surface Position message:

> **A.1.4.3.5 Latitude/longitude**
>
> The latitude/longitude field in the surface message will be a 34-bit field containing the latitude and longitude coding of the aircraft's surface position. The latitude *(*Y) and longitude *(*X) will each occupy 17 bits. The surface latitude and longitude encoding will contain surface CPR-encoded values in accordance with §A.1.7. The unambiguous range for local decoding of surface messages will be 166.5 km (90 NM). The positional accuracy maintained by the surface CPR encoding will be approximately 1.25 meters.
>
> ***Note:*** *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit).*

As with the Airborne message discussed above, detailed analysis of the CPR Surface Encoding and Decoding functions were performed several times using MATHCAD. Analysis has consistently indicated that the CPR encoding approximate accuracy of **1.25** meters does apply to virtually the entire possible encoding set. The worse case error was observed to be **-4.0840** feet (-1.24480320 meters) at an input latitude of **-87.0000** degrees and an input longitude of **-173.5000** degrees.

2.2. Surface CPR Encode/Decode Recommendation

Although the error observed in the previous section of this document is within the approximate limit of 1.25 meters specified in Appendix A, it is too close to be able to expect the tolerance to be maintained over all possible implementations. Therefore, it is herein recommended that the following restructure and note replace the existing note provided in section A.1.4.3.5.

> ***Note 1:*** *The latitude/longitude encoding is also a function of the CPR format value (the "F" bit) described above.*
>
> ***Note 2:*** *Although the positional accuracy of the surface CPR encoding is approximately 1.25 meters in most cases, implementers should be aware that the longitude position accuracy may only be approximately 3.0 meters when the latitude is either -87.0 +/-1.0 degrees or +87.0 +/- 1.0 degrees.*

<u>Commentary 1</u>: ***The analysis supporting the discussions above was conducted using the original CPR algorithm definitions which implemented a ¼ zone search for best value at the end of the decode to obtain the desired surface decode accuracy. The ¼ zone search has subsequently been deleted in later CPR definitions under the pretense that the accuracy requirements have been relaxed. Therefore, Note 2 requests the additional pad to an accuracy of 3.0 meters as opposed to requesting only 2.0 meters or so.***

<u>Commentary 2</u>: ***Those who implement state vector estimation or extrapolation filters should be aware of the longitudinal accuracy limitations of the CPR algorithm within one degree of either -87 or +87 degrees. Prior to rejecting test samples for being out of tolerance, the CPR error should be subtracted from the total error such that the filter error remains and is used as the criteria for acceptance or non-acceptance of the test sample.***